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**ADJUSTABLE AIR SEAL ON A FAN HUB**

## CROSS-REFERENCE TO RELATED APPLICATIONS

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This application claims priority of U.S. Provisional Patent Application Serial No. 60/455,181, filed March 17, 2003.

## BACKGROUND

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This invention relates to an air seal on the hub of a large axial flow fan. The air seal covers the annulus between the hub and inner ends of fan blades.

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Large industrial axial flow fans having diameters ranging from about one to ten meters or more are commonly used for moving air through cooling towers, heat exchangers and the like. A typical fan in such an application may have a diameter of about five meters and anywhere from eight to eighteen airfoil-shaped blades coupled to a rotatable hub.

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An exemplary mounting arrangement for the blades on large fans has a hub which fits on the drive shaft and a number of radially extending hub struts to which the blades are somewhat flexibly connected. The connection permits the blades to have limited motion in the axial direction, adjustment for pitch, and adjustment for radial length. The latter is important since the gap between the tip of the blades and the surrounding shroud should be small so that air "leakage" between the tips and shroud is relatively small. Air that may flow from the higher pressure downstream face of the fan to the lower pressure upstream face represents a loss of efficiency. A gap is, of course, important so that the ends of the blades do not collide with the shroud. Radial adjustment of the effective length of the blades allows the installer to have a small and uniform gap.

1        Air "leakage" at the inner ends of the blades should also  
be limited to promote fan efficiency. For smaller fans and  
those with fixed blades, a circular sheet of metal overlying  
5       the hub and covering any annulus between the hub and inner  
ends of the blades can form an effective air seal. For larger  
fans, and particularly for those with adjustable blades, a  
polygonal air seal closer to the inner ends of the blades is  
desirable. Furthermore, in addition to a flat sheet spanning  
10       the annulus, it may be desirable to have some axial extent of  
the air seal to minimize leakage around the downstream  
portions of the inner ends of the blades. In effect, the air  
seal is a shroud at the inner ends of the blades, that rotates  
15       with the blades.

When the diameter of the air seal at the hub of the fan  
becomes large, there can be problems in forming the air seal  
from a simple circular or polygonal sheet of metal. A  
structure for making increasingly large air seals is therefore  
20       desirable.

#### BRIEF SUMMARY OF THE INVENTION

There is, therefore, provided in practice of this  
25       invention an air seal for an axial flow fan comprising a  
generally round central sheet and a plurality of radially  
adjustable segments extending radially from the central sheet.  
Such a fan has a hub with a plurality of hub struts extending  
radially from the hub. A blade is mounted on each of the hub  
30       struts. Studs extend in the axial direction of the fan on  
each of the hub struts. Each of the segments of the air seal  
comprises a generally trapezoidal sheet spanning the space  
between adjacent hub struts with a plurality of slots near the  
35       radially extending edges of the sheet. Each slot extends in a

1 direction parallel to a radial line through the center of the  
segment. The slots fit over the studs on the hub struts.

#### 5 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates in plan view a fan hub, hub struts and  
some blade ends of a large axial flow fan.

FIG. 2 is a plan view of the air seal installed on the  
fan.

10 FIG. 3 is a perspective view of an air seal segment.

#### DESCRIPTION

A way of mounting blades on a large diameter axial flow  
15 fan is described and illustrated in U.S. Patent No. 6,022,191,  
the subject matter of which is hereby incorporated by  
reference. Such a large diameter axial flow fan has a central  
hub 10 which mounts on the drive shaft for the fan. A number  
of blade supporting hub struts 11 are connected to the hub and  
20 extend radially. A blade mounting structure 12 described in  
detail in the aforementioned patent, is at the end of each of  
the hub struts. Each of these mounting members connects to a  
blade 13. Only an end fragment of such a blade is illustrated  
25 since details of the mounting structure and blade are  
conventional and unimportant for understanding the structure  
of the air seal.

As previously indicated, an air seal is provided on the  
30 hub to cover the hub (to the extent required) and hub struts,  
and most importantly the space between the hub struts. The  
adjustable air seal for a large diameter fan has a central  
generally round sheet 16. Although it is conveniently made  
circular, as illustrated, the central sheet may be polygonal  
35 and only approximately circular. Also, instead of flat, the

1 sheet may be domed or otherwise shaped to better conform to  
the hub or provide structural stiffness. A number of radially  
adjustable segments 17 extend radially outwardly from the  
5 central sheet. The number of segments corresponds to the  
number of hub struts, i.e., the number of spaces between hub  
struts. The central sheet and segments are conveniently  
stamped and/or bent from 0.8 mm thick aluminum alloy sheet.

10 Each of the segments is generally trapezoidal in plan  
view. (As a segment of a ring, it could also be considered  
generally triangular.) "Generally trapezoidal" is a convenient  
shorthand for characterizing the segment even though it is  
preferred to be a five-sided polygon with the outer edge of  
15 the segment having two straight portions 18. For fans with  
larger numbers of blades the two straight portions are at such  
a small angle from each other that the segment appears  
approximately trapezoidal. Each radially extending side edge  
of the segment has a step 19 to a flange 21. Each flange  
20 overlies one of the hub struts and the central generally  
trapezoidal area 22 of the segment overlies (and seals) the  
space between adjacent hub struts.

At the outer edge of each segment there is a pair of  
25 straight walls 23 extending in the axial direction of the fan.  
Each straight portion of the wall is perpendicular to (or  
normal to) the nearest hub strut and therefore generally  
parallel to the root of a blade mounted on the nearest hub  
strut. It will be noted that when assembled on the fan hub  
30 and struts, the walls on adjacent segments form a straight  
wall parallel to the blade root. At the top of each of the  
two walls on a segment there is a lip 24 extending toward the  
center of the hub and generally parallel to the central area  
35 22 of the segment. A doubler 25 (hidden in the plan view) is

1 riveted or spot welded to the adjacent lips on the walls of  
the segment for stiffening and securing the walls together.

At the inner end of each segment (i.e., nearer the hub),  
5 a tab 26 is folded down so as to approximately engage the  
central sheet 16 of the air seal. The tab provides stiffening  
and helps close any gap between the central area of the  
segment and the generally circular central sheet. Since the  
10 segment is made of relatively thin sheet aluminum, stiffening  
by the inner tab, the radially extending side steps 19 and  
interconnected walls 23 at the outer edge is desirable. If  
further stiffening is desired (instead of using thicker  
sheet), additional folds or stiffening ribs may be added in  
15 the central generally trapezoidal area of the segment.  
Conversely, the generally trapezoidal segment may be made  
essentially flat without the inner tab, side steps or outer  
walls, where the metal sheet is sufficiently stiff without  
these bends. Such "flat" segments may include outer walls for  
20 sealing adjacent the blade roots.

Each of the hub struts has an inner stud 27 extending  
through the edge of the central sheet of the air seal. There  
is a second outer stud 28 nearer the outer end of each of the  
25 hub struts. The two studs on each hub strut extend in the  
axial direction of the fan.

There are slots 29 in the flanges along each side edge of  
each segment. The segments are placed on the hub struts so  
30 that the two studs on each hub strut pass through respective  
slots in the edge flanges of the segment. Segments are  
assembled to cover all of the spaces between hub struts so the  
flanges on adjacent segments overlap and each stud passes  
through the two flanges of the adjacent segments.

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1           A generally z-shaped strut 31 is bolted (or riveted or  
welded) to the inwardly extending lip at the top of the wall.  
The other end of the strut has a slot 32 that fits over the  
5       outer stud on the hub strut. The z-shaped struts stiffen the  
walls when the entire assembly is bolted together.

          The studs are threaded and receive nuts for securing the  
entire assembly. As desired, one may use elastomeric buffers,  
washers, lock washers, castle nuts, ordinary nuts or other  
10       conventional assembly products to assure a tight, trouble free  
assembly. When assembled, each of the inner studs secures an  
edge of the round central sheet and the flanges on adjacent  
radially extending segments. Similarly, the outer studs  
15       secure the outer portions of the flanges on adjacent segments  
as well as the z-shaped struts.

          It will be noted that the slots in the flanges extend in  
a direct parallel to a radial line through the center of the  
generally trapezoidal segment. Thus, each segment can be  
20       moved radially inwardly or outwardly as appropriate for  
approaching the inner ends of the adjacent blades. If the  
segments are made flat instead of with radially extending side  
flanges, the slots also extend parallel to a radial centerline  
25       through the generally trapezoidal segment.

          In the illustrated embodiment, the air seal is rather  
like a shallow bowl placed on top of the hub and hub struts.  
Thus, the axially extending walls 23 are adjacent to the  
30       downstream or trailing edge of the blades. (This alignment is  
referred to as "top" herein since most of such large fans are  
used in cooling towers where the fan draws air from within the  
top of the cooling tower to exhaust upwardly.) An alternative  
arrangement may be used in the event it is desired to have the  
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1 axially extending walls be adjacent a greater length of the  
root of the blades.

5 In such an arrangement studs are provided on the lower  
(upstream) side of the hub struts. In effect, the hub is then  
set down in the center of a generally bowl-shaped air seal.  
Openings are left at the ends of the outer walls of the  
segments for clearance around hub struts and/or the blade  
mounting structure. The hub struts are passed through such  
10 holes for connection to the hub, ordinarily before the blades  
are mounted.

Although described as if the hub and hub struts were set  
down into the bowl-shaped air seal, it will be apparent that a  
15 more convenient way of assembling is to do it upside down with  
the air seal on top during assembly. It will also be apparent  
that somewhat different steps, flanges and tabs may be used  
and/or the walls be made higher than in the illustrated  
embodiment. The general principles, however, remain the same.  
20 Slots in the edges of the generally trapezoidal segments  
remain parallel to a radial line through the center of the  
segment so that the radial position of the segment can be  
adjusted.

25 Although the segment is generally trapezoidal since the  
tab 26 is bent down along a straight line, it should be  
apparent that a more triangular segment is quite equivalent  
where a tab is carried much nearer the center of the assembly.  
Such a "tail" at the inner end of the segment is not regarded  
30 as changing the overall shape from generally trapezoidal.  
Similarly, in the illustrated embodiment, the outer walls 23  
are straight to parallel the roots of adjacent blades making,  
in effect, a five-sided "trapezoid". It should be apparent  
35 that the segment is generally trapezoidal if the segments are

1 made with a single straight wall (so that they are actually  
trapezoidal) or if made with a difficult to fabricate curved  
wall at the outer edge.

5 If desired, the outer walls on the segments may be curved  
in the axial direction of the fan to more closely conform to  
the roots of the blades which are at an angle to the axial  
direction. This may be desirable in the second embodiment  
which is not illustrated, where the air seal is on the  
10 upstream face of the hub and hub struts. Curved outer walls  
may also be more efficient aerodynamically.

It is also considered equivalent where two generally  
trapezoidal segments are formed from a single wider sheet so  
15 as to span the two spaces between three hub struts. Such a  
combining of two segments may or may not be secured to the  
middle one of the three adjacent hub struts since the joinder  
of adjacent segments may be made stiff enough that  
intermediate bolting is not needed. In such an equivalent  
20 embodiment, the slots in the radially extending side edges of  
the segment(s) extend in a direction parallel to the  
centerline of the combined segments to permit radial  
adjustment.

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